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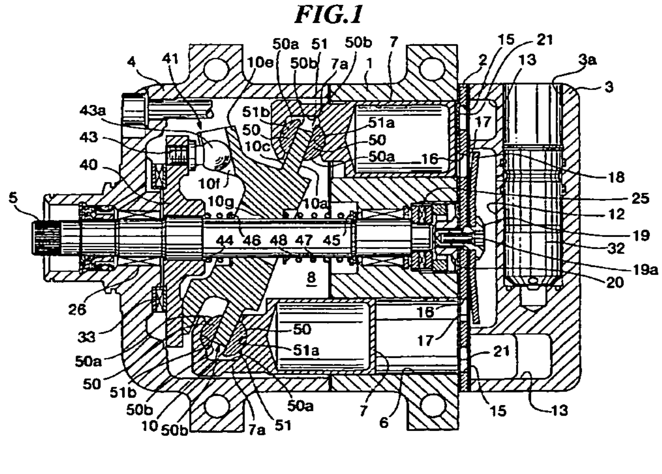
(54) Variable capacity swash plate compressor and method of surface treatment of a swash plate thereof

(57) A variable capacity swash plate compressor includes a cylinder block (1) having a central through hole and at least one cylinder bore (6) formed about the central through hole, a drive shaft (5) rotatably arranged in the central through hole, a rotary member (40) rigidly fitted on the drive shaft (5) for rotation in unison therewith, a swash plate (10, 110) slidably and tiltably fitted on the drive shaft (5), the swash plate (10, 110) having a sliding surface (10a, 10c), a linkage (41) connecting the rotary member (40) and the swash plate (10, 110) such that the swash plate (10, 110) rotates in unison with the rotary member (40) as the rotary member (40) rotates, at least one shoe (50, 150) arranged to perform relative rotation on the sliding surface (10a, 10c) of the swash plate (10, 110) with respect thereto, and at least one piston (7, 107) connected to the swash plate (10, 110) via a corresponding one of the at least one shoe (50, 150), the or each piston (7, 107) being reciprocable within a corresponding one of the at least one cylinder bore (6) as the swash plate (10, 110) rotates. The swash plate (10, 110) has a protruding portion (10e) formed thereon, which protruding portion (10e) forms a component part of the linkage (41). The swash plate (10, 110) including the protruding portion (10e) is subjected to surface treatment by gas sulphonitriding or electroless nickel-phosphorus-boron plating.

FIG.1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a variable capacity swash plate compressor and a method of surface treatment of a swash plate of the variable capacity swash plate compressor.

Description of the Prior Art

In a variable capacity swash plate compressor, a shaft has a thrust flange rigidly fitted on a front-side portion thereof for transmitting torque of the shaft to the swash plate. The thrust flange is rotatably supported on an inner wall of the front head by a thrust bearing. The thrust flange and the swash plate are connected by a linkage. The swash plate is tiltable with respect to a plane perpendicular to the shaft.

The swash plate is slidably and tiltably fitted on the shaft. A shoe for slidably supporting one end of a connecting rod is retained on a sliding surface of the swash plate by a retainer. The connecting rod has the other end thereof secured to a piston.

The linkage is comprised of a bracket formed on a front-side surface of the swash plate, a linear guide slot formed in the bracket, and a rod screwed into the thrust flange. A spherical end portion of the rod is engaged with the guide slot in a manner relatively slidable with respect to the guide slot.

The shaft, the swash plate including the bracket, and the rod are each formed of a ferrous material.

Torque of an engine installed on an automotive vehicle is transmitted to the shaft. Torque of the shaft is transmitted to the swash plate via the thrust flange and the linkage to cause rotation of the swash plate.

The rotation of the swash plate causes relative rotation of the shoe on the sliding surface of the swash plate with respect to the swash plate, whereby the torque transmitted from the swash plate is converted into reciprocating motion of the piston. As the piston reciprocates within a cylinder bore, the volume of space within the cylinder bore changes, whereby suction, compression and delivery of refrigerant gas are carried out sequentially. The inclination of the swash plate varies with pressure in a crankcase in which the swash plate is received, and high pressure refrigerant gas is discharged in an amount corresponding to an angle of the inclination of the swash plate.

In the variable capacity swash plate compressor constructed as above, when the compressor is in operation, the shoe slides on the sliding surface of the swash plate (relatively rotates with respect to the swash plate), an inner peripheral surface of the swash plate slides on a peripheral surface of the shaft, and the spherical end portion of the rod slides in the guide slot (relatively slides).

Therefore, conventionally, to reduce abrasion of the swash plate, sliding surfaces of a swash plate are coated with a bronze-based material by thermal spraying, or with molybdenum disulfide (MoS2) by application, or the whole swash plate is subjected to quenching/tempering.

However, the above treatment methods suffer from the problem that hardness of the treated surfaces of the swash plate is increased to a large extent, so that when polishing is carried out as required for correcting distortions of the surfaces of the swash plate caused by such heat treatment, polishing tools badly wear in the polishing operation.

Further, in the surface treatment of the sliding surfaces of the swash plate, it is required to carry out abrasive blasting, sanding or the like as pre-treatment prior to the surface treatment and polishing as posttreatment posterior to the same, which makes the whole surface treatment process complicated and troublesome.

Moreover, in general, surface treatment by thermal spraying or application has a difficulty in providing coating on a protruding portion of a workpiece, such as the bracket formed on the swash plate, and hence the resulting coating formed thereon is not uniform. One conventional or possible solution to this problem is to construct a swash plate by two component parts which are separately subjected to surface treatment, and joined into a unitary member after the treatment. However, this method not only increases manufacturing costs of the swash plate but also causes distortion of the sliding surfaces of the swash plate due to thermal stresses produced when the component parts are joined to each other.

SUMMARY OF THE INVENTION

It is a first object of the invention to provide a variable capacity swash plate compressor which comprises a swash plate formed to have sliding surfaces free or almost free from distortion without carrying out polishing operation thereon, or increasing manufacturing costs of the compressor.

It is a second object of the invention to provide a method of surface treatment of a swash plate of a variable capacity swash plate compressor, which is capable of treating surfaces of the swash plate such that the resulting surfaces of the swash plate are free or almost free from distortion without carrying out polishing operation thereon or increasing manufacturing costs of the compressor.

To attain the first object, according to a first aspect of the present invention, there is provided a variable capacity swash plate compressor including a cylinder having a central through hole and at least one cylinder bore formed about the central through hole, a drive shaft rotatably arranged in the central through hole, a rotary member rigidly fitted on the drive shaft for rotation in unison with the drive shaft, a swash plate slidably and tilt-

ably fitted on the drive shaft, the swash plate having a sliding surface, a linkage connecting the rotary member and the swash plate in a manner such that the swash plate rotates in unison with the rotary member as the rotary member rotates, at least one shoe performing relative rotation on the sliding surface of the swash plate with respect to the swash plate, and at least one piston connected to the swash plate via a corresponding one of the at least one shoe, each of the at least one piston reciprocating within a corresponding one of the at least one cylinder bore as the swash plate rotates, wherein the swash plate has a protruding portion formed thereon, the protruding portion forming a component part of the linkage,

The variable capacity swash plate compressor according to the first aspect of the invention is characterized in that the swash plate including the protruding portion is subjected to surface treatment by gas sulphonitriding.

According to this variable capacity swash plate compressor, the swash plate including the protruding portion is subjected to the surface treatment by gas sulphonitriding. Therefore, the surfaces of the swash plate including the protruding portion are improved in wear resistance through hardening, and at the same time enhanced in lubricity.

To attain the first object, according to a second aspect of the present invention, there is provided a variable capacity swash plate compressor, which is characterized in that the swash plate including the protruding portion is subjected to surface treatment by electroless nickel-phosphorus-boron plating.

According to this variable capacity swash plate compressor, the swash plate including the protruding portion is subjected to the surface treatment by electroless nickel-phosphorus-boron plating. Therefore, the surfaces of the swash plate including the protruding portion are improved in wear resistance through hardening, and at the same time enhanced in lubricity.

Preferably, a nickel-based coating formed on the swash plate including the protruding portion by the electroless nickel-phosphorus-boron plating contains 0.5 to 3.0 wt% of phosphorus and 0.05 to 2.0% of boron.

To attain the second object, according to a third aspect of the invention, there is provided a method of surface treatment of a swash plate of a variable capacity swash plate compressor including a cylinder having a central through hole and at least one cylinder bore formed about the central through hole, a drive shaft rotatably arranged in the central through hole, a rotary member rigidly fitted on the drive shaft for rotation in unison with the drive shaft, the swash plate slidably and tiltably fitted on the drive shaft, the swash plate having a sliding surface, a linkage connecting the rotary member and the swash plate in a manner such that the swash plate rotates in unison with the rotary member as the rotary member rotates, at least one shoe performing relative rotation on the sliding surface of the swash plate with respect to the swash plate, and at least one piston connected to the swash plate via a corresponding one of the at least one shoe, each of the at least one piston reciprocating within a corresponding one of the at least one cylinder bore as the swash plate rotates, wherein the swash plate has a protruding portion formed thereon, the protruding portion forming a component part of the linkage.

The method according to the third aspect of the invention is characterized in that the surface treatment of the swash plate including the protruding portion is carried out by gas sulphonitriding.

According to this method, it is possible to treat the surfaces of the swash plate including the protruding portion in a single operation, and thereby provide a uniform coating all over the swash plate even if the swash plate has a complicated shape. Further, since the surface treatment by gas sulphonitriding is carried out at a sufficiently low temperature, the resulting surfaces of the swash plate including the sliding surface are free or almost free from distortion, which makes it unnecessary to carry out polishing of the treated surfaces of the swash plate after the surface treatment.

To attain the second object, according to a fourth aspect of the present invention, there is provided a method of surface treatment of a swash plate of a variable capacity swash plate compressor, which is characterized in that the surface treatment of the swash plate including the protruding portion is carried out by electroless nickel-phosphorus-boron plating.

This method provides the same advantageous effects as obtained by the method according to the third embodiment.

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description taken in conjunction with accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view showing the whole arrangement of a variable capacity swash plate compressor according to a first embodiment of the invention; and

FIG. 2 is a longitudinal sectional view showing the whole arrangement of a variable capacity swash plate compressor according to a second embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will now be described in detail with reference to drawings showing preferred embodiments thereof.

FIG. 1 shows the whole arrangement of a variable capacity swash plate compressor according to a first embodiment of the invention.

The variable capacity swash plate compressor has a cylinder block 1 having one end thereof secured to a rear head 3 via a valve plate 2 and the other end thereof secured to a front head 4. The cylinder block 1 has a plurality of cylinder bores 6 axially formed therethrough at predetermined circumferential intervals about a shaft 5 arranged in a central through hole axially formed in the center of the cylinder block 1. Each cylinder bore 6 has a piston 7 slidably received therein.

Within the front head 4, there is formed a crankcase 8. The crankcase 8 has a swash plate 10 received therein. The swash plate 10 is slidably and tiltably fitted on the shaft 5. The swash plate 10 is connected to the piston 7 via shoes 50, 50. The shoes 50, 50 are arranged in a manner sandwiching the swash plate 10, with plane surfaces 50b, 50b thereof held in contact with sliding surfaces 10a, 10c of the swash plate 10, respectively.

The piston 7 has one end portion 7a thereof formed with a recess 51 in which is received a peripheral portion of the swash plate 10. The recess 51 has concave portions 51a, 51b formed in respective inner surfaces thereof in a manner opposed to each other in a direction of a movement of the piston 7. Hemispherical portions 50a, 50a of the shoes 50, 50 are slidably supported or received in the concave portions 51a, 51b, respectively.

Within the rear head 3, there are formed a discharge chamber 12 and a suction chamber 13 surrounding the discharge chamber 12. Further, the rear head 3 is formed therein with a suction port 3a communicating with an outlet port, not shown, of an evaporator, not shown, and a communication passage, not shown, communicating between the suction port 3a and the suction chamber 13. A capacity control valve 32 is arranged in an intermediate portion of the communication passage, for controlling the pressure in the crankcase 8.

The valve plate 2 is formed with refrigerant outlet ports 16 for respectively communicating between the cylinder bores 6 and the discharge chamber 12, and refrigerant inlet ports 15 for respectively communicating between the cylinder bores 6 and the suction chamber 13. The refrigerant outlet ports 16 and the refrigerant inlet ports 15 are arranged at predetermined circumferential intervals about the shaft 5, respectively. Each refrigerant outlet port 16 is opened and closed by a discharge valve 17. The discharge valve 17 is fixed to the valve plate 2 on the rear head side by a bolt 19 and a nut 20 together with a valve stopper 18.

On the other hand, each refrigerant inlet port 15 is opened and closed by a suction valve 21 arranged between the valve plate 2 and the cylinder block 1. The bolt 19 has a guide hole 19a formed therethrough for guiding high-pressure refrigerant gas from the discharge chamber 12 to a radial bearing 24 and a thrust bearing 25.

The radial bearing 24 and the thrust bearing 25 support a rear-side end of the shaft 5, while a radial bearing 26 rotatably supports a front-side end of the shaft 5.

The shaft 5 has a thrust flange 40 rigidly fitted on a front-side portion thereof for transmitting torque of the shaft 5 to the swash plate 10. The thrust flange 40 is supported on an inner wall of the front head 4 by a thrust bearing 33. The thrust flange 40 and the swash plate 10 are connected by a linkage 41. The swash plate 10 is tiltable with respect to a plane perpendicular to the shaft 5.

On the shaft 5 are fitted coiled springs 44 and 47 between the thrust flange 40 and a stopper 46 arranged on the shaft 5 and between stoppers 45 and 48 both arranged on the shaft 5, respectively.

The linkage 41 is comprised of a bracket (protruding portion) 10e formed on the sliding surface (front-side surface) 10c of the swash plate 10, a linear guide slot 10f formed in the bracket 10e, and a rod 43 screwed into a swash plate-side surface 40a of the thrust flange 40. The longitudinal axis of the guide slot 10f is tilted through a predetermined angle with respect to the front-side surface 10c of the swash plate 10. A spherical end portion 43a of the rod 43 is relatively slidably engaged with the guide slot 10f.

The shaft 5, the swash plate 10 including the bracket 10e, the thrust flange 40, the rod 43 and the shoes 50 are each formed of a ferrous material. The swash plate 10 including the bracket 10e is subjected to surface treatment by gas sulphonitriding (multinite nitrocarburizing) or electroless nickel-phosphorus-boron plating.

Gas sulphonitriding is a method of diffusing nitrogen and sulfur into a surface of steel within an atmosphere of nitrogen gas N2 containing sulfur S, by using ammonia NH_3 and an X gas (sulfurizing element gas) comprising a slight amount of sulphur S. Electroless nickel-phosphorus-boron plating is a method of forming a nickel-based coating containing e.g. 0.5 to 3.0 wt% of phosphorus and 0.05 to 2.0 wt% of boron by electroless plating. The methods are both capable of improving wear resistance or lubricity of the swash plate 10 including the bracket 10e.

Next, the operation of the variable capacity swash plate compressor constructed as above will be described.

Torque of an engine, not shown, installed on an automotive vehicle, not shown, is transmitted to the shaft 5. Torque of the shaft 5 is transmitted from the thrust flange 40 to the swash plate 10 via the linkage 41 to cause rotation of the swash plate 10.

The rotation of the swash plate 10 causes relative rotation of the shoes 50 on the sliding surfaces 10a, 10c of the swash plate 10 with respect to the swash plate 10, whereby the torque transmitted from the swash plate 10 is converted into reciprocating motion of the piston 7. As the piston 7 reciprocates within the cylinder bore 6, the volume of space (compression chamber) within the cylinder bore 6 changes, whereby, suction, compression and delivery of refrigerant gas are carried out sequentially, to discharge high-pressure refrigerant gas in an amount corresponding to an angle of inclination of

the swash plate 10. During the suction stroke, the suction valve 21 opens, whereby low-pressure refrigerant gas is drawn from the suction chamber 13 into the compression chamber within the cylinder bore 6. During the discharge stroke, the discharge valve 17 opens, whereby high-pressure refrigerant gas is delivered from the compression chamber to the discharge chamber 12.

When thermal load on the compressor decreases, the capacity control valve 32 closes the communication passage, whereby the pressure within the crankcase 8 is increased. As a result, the angle of inclination of the swash plate becomes smaller, which decreases the stroke of the piston 7 to thereby reduce the delivery quantity or capacity of the compressor.

On the other hand, when the thermal load on the compressor increases, the capacity control valve 32 opens the communication passage, whereby the pressure within the crankcase 8 is decreased. As a result, the angle of inclination of the swash plate becomes larger, which increases the stroke of the piston 7 to thereby increase the delivery quantity or capacity of the compressor.

During the above operation of the compressor, the shoes 50 slide on the sliding surfaces 10a, 10c of the swash plate 10 (relatively rotate with respect to the swash plate), respectively, an inner peripheral surface of a central through hole 10g formed through the swash plate 10 slides on an outer peripheral surface of the shaft 5, and the spherical end portion 43a of the rod 43 slides (relative slides) in the guide slot 10f.

According to the variable capacity swash plate compressor of the embodiment, the swash plate 10 including the bracket 10e is subjected to surface treatment by gas sulphonitriding or electroless nickel-phosphorus-boron plating, so that the surface of the swash plate 10 including the bracket 10e is improved in wear resistance through hardening, and at the same time enhanced in lubricity.

Further, in the surface treatment of the swash plate 10 including the bracket 10e by gas sulphonitriding or electroless nickel-phosphorus-boron plating, it is possible to treat the sliding surfaces 10a, 10c, the inner surface of the central through hole 10g, and the bracket 10e, in a single operation, and what is more, uniform coating can be provided all over the swash plate 10 even if the plate 10 has a complicated shape. Further, the surface treatment is carried out at a sufficiently low temperature, which causes almost no or only slight distortion of the sliding surfaces of the swash plate 10. Therefore, no polishing operation is required after the surface treatment, which facilitates the surface-treating process. Further, the swash plate is not required to be formed by a plurality of separate component parts, which contributes to reduction of manufacturing costs of the compressor.

FIG. 2 shows the whole arrangement of a variable capacity swash plate compressor according to a second embodiment of the invention. Component parts and elements corresponding to those of the first embodiment are indicated by identical reference numerals, and description thereof is omitted.

In the first embodiment shown in FIG. 1, the present invention is applied to a type of variable capacity swash plate compressor in which the pair of shoes 50, 50 are arranged in a manner sandwiching the swash plate 10 and supported directly in one end portion 7a of the piston 7, while in the second embodiment shown in FIG. 2, the invention is applied to a type of variable capacity swash plate compressor in which a connecting rod 11 is provided which connects a shoe 150 and a piston 107.

A swash plate 110 is slidably and tiltably fitted on a shaft 5. A shoe 150, which slidably supports one end 11a, spherical in shape, of a corresponding one of connecting rods 111, is retained on a sliding surface 10a of the swash plate 10 by a retainer 53. The retainer 53 is mounted on a boss 10b of the swash plate 10 in a manner supported by a lock plate 55 fixed to the boss 10b by a stopper 54. The connecting rod 11 has the other end 11b thereof connected to the piston 7.

The shoe 150 is comprised of a shoe body 151 slidably supporting a front-side surface of the one end lla of the connecting rod 11 and a washer 152 for slidably supporting or retaining a rear-side surface of the one end 11a of the same.

The swash plate 110 including the bracket 10e is subjected to surface treatment by gas sulphonitriding or electroless nickel-phosphorus-boron plating, similarly to the first embodiment.

The basic operation of the FIG. 2 variable capacity swash plate compressor according to the second embodiment is identical to that of the FIG. 1 compressor according to the second embodiment, and the former provides the same effects as obtained by the latter.

It is further understood by those skilled in the art that the foregoing is the preferred embodiment of the invention, and that various changes and modification may be made without departing from the spirit and scope thereof.

Claims

1. A variable capacity swash plate compressor comprising a cylinder block (1) having a central through hole and at least one cylinder bore (6) formed about the central through hole, a drive shaft (5) rotatably arranged in the central through hole, a rotary member (40) rigidly fitted on the drive shaft (5) for rotation in unison therewith, a swash plate (10, 110) which is slidably and tiltably fitted on the drive shaft (5) and has a sliding surface (10a, 10c), a linkage (41) connecting the rotary member (40) and the swash plate (10, 110) such that the swash plate (10, 110) can rotate in unison with the rotary member (40) as the rotary member (40) rotates, at least one shoe (50, 150) arranged to perform relative rotation on

the sliding surface (10a, 10c,) of the swash plate (10, 110) with respect thereto, and at least one piston (7, 107) connected to the swash plate (10, 110) via a corresponding one of said at least one shoe (50, 150), the or each piston (7, 107) being reciprocable within a corresponding one of said at least one cylinder bore (6) as the swash plate (10, 110) rotates, wherein the swash plate (10, 110) has a protruding portion (10e) formed thereon, the protruding portion (10e) forming a component part of the linkage (41),

characterised in that the swash plate (10, 110) including the protruding portion (10e) has been subjected to surface treatment by gas sulphonitriding.

2. A variable capacity swash plate compressor comprising a cylinder block (1) having a central through hole and at least one cylinder bore (6) formed about the central through hole, a drive shaft (5) rotatably arranged in the central through hole, a rotary member (40) rigidly fitted on the drive shaft (5) for rotation in unison therewith, a swash plate (10, 110) which is slidably and tiltably fitted on the drive shaft (5) and has a sliding surface (10a, 10c), a linkage (41) connecting the rotary member (40) and the swash plate (10, 110) such that the swash plate (10, 110) can rotate in unison with the rotary member (40) as the rotary member (40) rotates, at least one shoe (50, 150) arranged to perform relative rotation on the sliding surface (10e, 10c) of the swash plate (10, 110) with respect thereto, and at least one piston (7, 107) connected to the swash plate (10, 110) via a corresponding one of said at least one shoe (50, 150), the or each piston (7, 107) being reciprocable within a corresponding one of said at least one cylinder bore (6) as the swash plate (10, 110) rotates, wherein the swash plate (10, 110) has a protruding portion (10e) formed thereon, the protruding portion (10e) forming a component part of the linkage (41),

characterised in that the swash plate (10, 110) including the protruding portion (10e) has been subjected to surface treatment by electroless nickel-phosphorus-boron plating.

3. A variable capacity swash plate compressor according to claim 2, wherein a nickel-based coating formed on the swash plate (10, 110) including the protruding portion (10e) by electroless nickel-phosphorus-boron plating, contains 0.5 to 3.0 wt% of phosphorus and 0.05 to 2.0 wt% of boron.

4. A method of surface treating a swash plate (10, 110) of a variable capacity swash plate compressor comprising a cylinder block (1) having a central through hole and at least one cylinder bore (6) formed about the central through hole, a drive shaft (5) rotatably arranged in the central through hole, a rotary member (40) rigidly fitted on the drive shaft (5) for rotation in unison therewith, the swash plate (10, 110) being slidably and tiltably fitted on the drive shaft (5) and having a sliding surface (10a, 10c), a linkage (41) connecting the rotary member (40) and the swash plate (10, 110) such that the swash plate (10, 110) can rotate in unison with the rotary member (40) as the rotary member (40) rotates, at least one shoe (50, 150) arranged to perform relative rotation on the sliding surface (10a, 10c) of the swash plate (10, 110) with respect thereto, and at least one piston (7, 107) connected to the swash plate (10, 110) via a corresponding one of said at least one shoe (50, 150), the or each piston (7, 107) being reciprocable within a corresponding one of said at least one cylinder bore (6) as the swash plate (10, 110) rotates, wherein the swash plate (10, 110) has a protruding portion (10e) formed thereon, the protruding portion (10e) forming a component part of the linkage (41),

characterised in that the surface treatment of the swash plate (10, 110) including the protruding portion (10e) is carried out by gas sulphonitriding.

5. A method of surface treating a swash plate (10, 110) of a variable capacity swash plate compressor comprising a cylinder block (1) having a central through hole and at least one cylinder bore (6) formed about the central through hole, a drive shaft (5) rotatably arranged in the central through hole, a rotary member (40) rigidly fitted on the drive shaft (5) for rotation in unison therewith, the swash plate (10, 110) being slidably and tiltably fitted on the drive shaft (5) and having a sliding surface (10a, 10c), a linkage (41) connecting the rotary member (40) and the swash plate (10, 110) such that the swash plate (10, 110) rotates in unison with the rotary member (40) as the rotary member (40) rotates, at least one shoe (50, 150) arranged to perform relative rotation on the sliding surface (10a, 10c) of the swash plate (10, 110) with respect thereto, and at least one piston (7, 107) connected to the swash plate (10, 110) via a corresponding one of said at least one shoe (50, 150), the or each piston (7, 107) being reciprocable within a corresponding one of said at least one cylinder bore (6) as the swash plate (10, 110) rotates, wherein the swash plate (10, 110) has a protruding portion (10e) formed thereon, the protruding portion (10e) forming a component part of the linkage (41),

characterised in that the surface treatment of swash plate (10, 110) including the protruding portion (10e) is carried out by electroless nickel-phosphorus-boron plating.

6. A method according to claim 5, wherein a nickel-based coating formed on the swash plate (10, 110) including the protruding portion (10e) by electroless nickel-phosphorus-boron plating, contains 0.5 to 3.0 wt% of phosphorus and 0.05 to 2.0 wt% of boron.

FIG.1

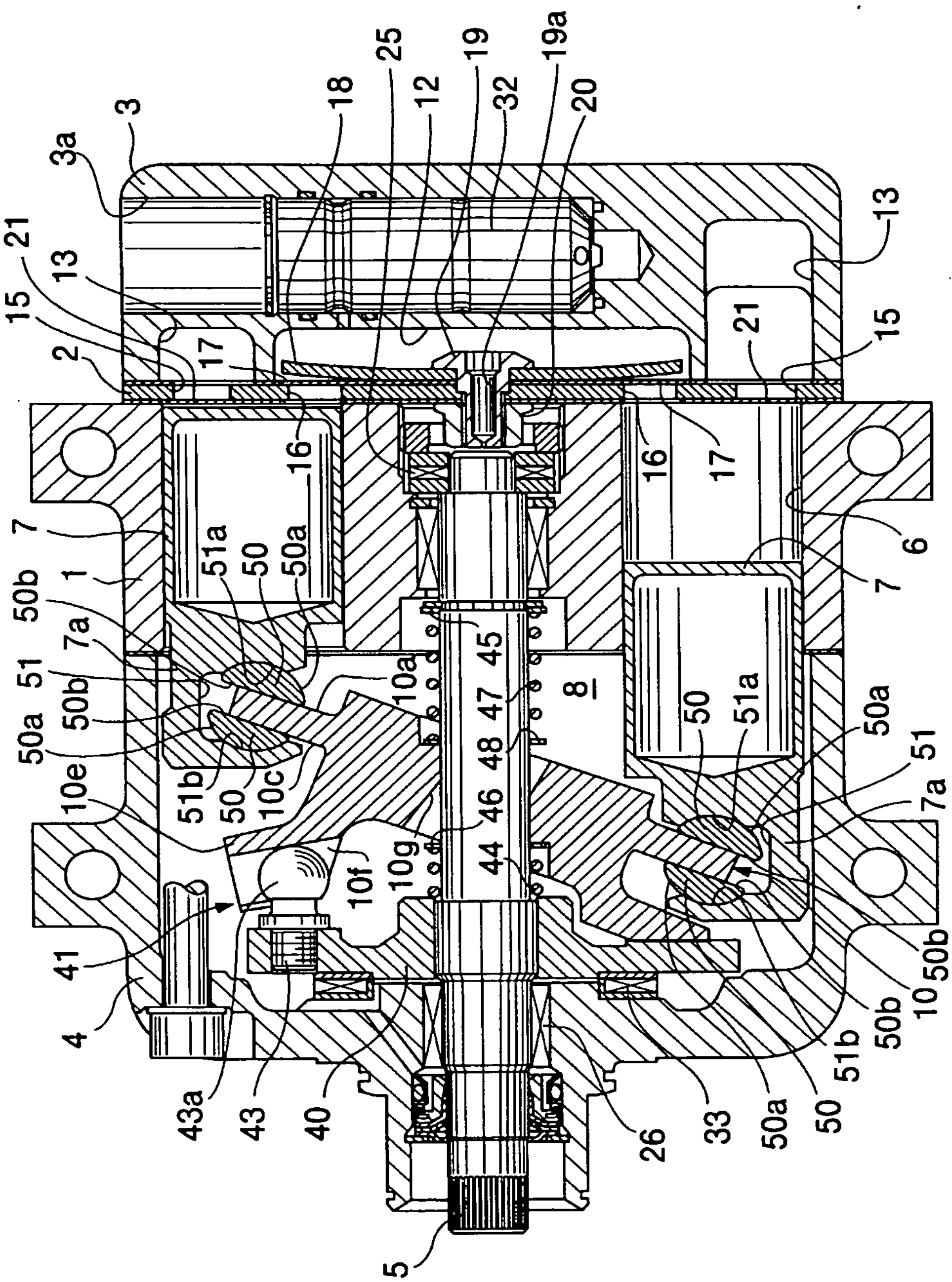
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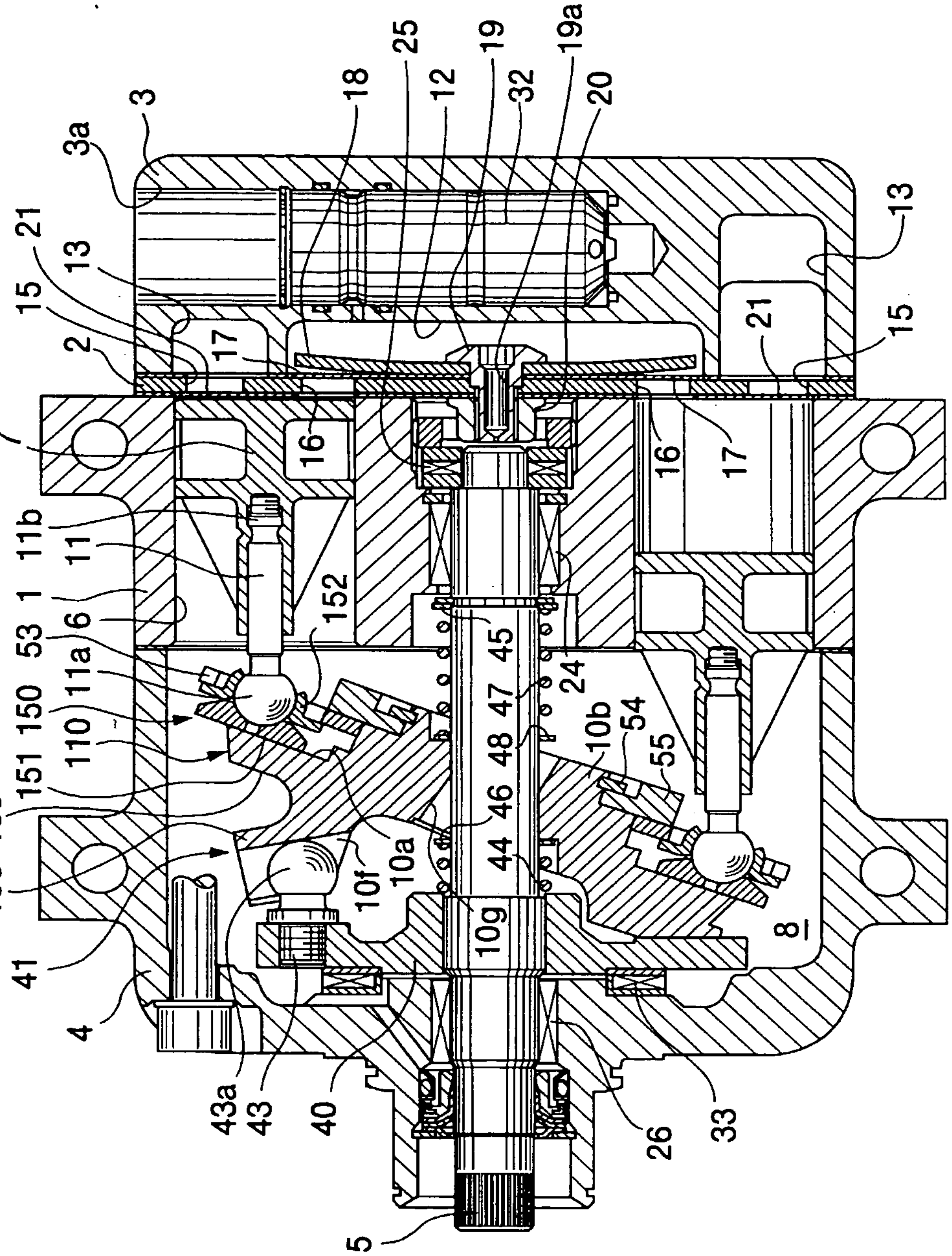
FIG.2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